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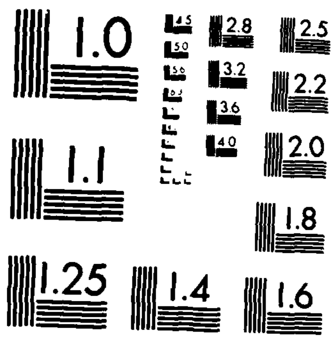

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COGNITIVE SPEED AND PERFORMANCE IN BASIC ELECTRICITY AND ELECTRONICS (BE&E) SCHOOL

NAVY PERSONNEL RESEARCH
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DEVELOPMENT CENTER
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COGNITIVE SPEED AND PERFORMANCE IN BASIC ELECTRICITY AND ELECTRONICS (BE&E) SCHOOL

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A battery of cognitive speed tests was programmed for administration via microcomputer and given to 155 entering students at the BE&E school, Naval Training Center, San Diego. The tests measured (1) reaction time, the time in milliseconds it takes a subject to respond to simple and complex stimuli, and (2) inspection time, the shortest time, in milliseconds, a subject needs to discriminate which of two briefly presented lines is longer. The substantial relationships found between cognitive speed test scores

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) and rate of progress in the self-paced BE&E course support the continued investigation of cognitive speed tests as a potentially useful predictor of technical school performance.

FOREWORD

This research was conducted within the in-house independent laboratory research program under a project entitled Cognitive Speed and Learning Potential (PE61152N, ZR000-01-042.003). During FY84 the work has transitioned to Future Technologies for Manpower and Personnel (PE62763, RF63-521-806). The primary objectives of this effort were to improve the Navy's ability to select technically trainable personnel from a dwindling manpower pool and to determine whether speed of information processing is related to other kinds of intellectual aptitude.

This report describes a first attempt by the Navy Personnel Research and Development Center to investigate the relationship between cognitive speed and success in a technical training program. The battery of cognitive speed tests will be further developed and evaluated in upcoming research in both military and civilian settings.

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SUMMARY

Problem

There is a longstanding, widely recognized need for methods of testing aptitude that are fast, easy to administer, culture-free, and predictive of meaningful criteria, such as achievement in or graduation from training. Current military testing programs employing conventional paper-and-pencil tests appear to have reached the upper limit of their utility many years ago. Recent developments in the field of cognitive science and in computer applications to testing offer considerable promise for improving the technology for discovering and measuring an individual's talents and aptitudes.

Purpose

The purpose of the present effort is to develop computer-presented tests of cognitive speed and to assess their effectiveness as predictors of performance. Two hypothesized measures of cognitive speed--inspection time (IT) and reaction time (RT)--were investigated.

Approach

A battery of cognitive speed tests was programmed for administration via microcomputer and given to 155 entering students at the basic electricity and electronics (BE&E) school, Naval Training Center, San Diego. The tests measured (1) reaction time, the time in milliseconds it takes a subject to respond to simple and complex stimuli, and (2) inspection time, the shortest time, in milliseconds, a subject needs to discriminate which of two briefly presented lines is longer.

Results

Significant relationships were found between scores on several of the cognitive speed tests and rate of progress in the self-paced BE&E course. The results support the continued investigation of cognitive speed as a potentially useful predictor of technical school performance.

CONTENTS

INTRODUCTION

Problem

There is a longstanding, widely recognized need for improved methods of testing aptitude that are fast, easy to administer, culture-free, and predictive of meaningful criteria, such as achievement in or graduation from training. While current military testing programs employing conventional paper-and-pencil tests appear to have reached the upper limit of their utility, recent developments in the field of cognitive science and in computer applications to testing may provide alternative means for discovering and measuring an individual's talents and aptitudes. One approach currently being pursued is the investigation of individual differences in basic information processing skills (e.g., Hunt, 1983; Sternberg, 1981). In particular, some scientists have reported that simple tests that provide an index of how quickly and accurately a person can perceive a simple stimulus may yield a surprising amount of information about that person's underlying mental capacity (e.g., Brand & Deary, 1982).

Purpose

The purpose of the present effort is to develop computer-presented tests of cognitive speed and to assess their effectiveness as predictors of performance. Two hypothesized measures of cognitive speed--inspection time (IT) and reaction time (RT)--were investigated.

Background

IT tests generally require the subject to discriminate between rapidly presented stimuli, usually lines. For example, a subject might be shown two horizontal lines of unequal length and asked whether the longer line was on the right or left. The duration of time the subject sees the lines is gradually reduced until his or her threshold is found, with threshold being defined as the duration in milliseconds at which the subject's judgment would be correct on a predetermined percentage, say 90 percent, of the trials. An analogous series of trials using vertical lines is sometimes employed along with or in place of horizontal lines. The use of forward and backward masks--long lines that the subject perceives as covering the two stimulus lines before and after they are presented--ensures that responses are based on information that has actually been encoded rather than on afterimages or other peripheral (as opposed to central) processes. The subject's threshold value is therefore presumed to be largely a function of his/her speed of information processing.

Experimental studies using IT procedures have found significant correlations between IT and more traditional measures of intelligence (IQ) (e.g., Nettlebeck & Lally, 1976; Brand, in press), and between IT and the ability to perform certain mechanical tasks (e.g., Nettlebeck, Chesire, & Lally, 1979). Also, analogous research involving speed of processing auditory stimuli has demonstrated a positive relationship to aptitude (e.g., Raz, Willerman, Ingmundson, & Hanlon, 1983). However, many of the studies suffer from methodological shortcomings (Irwin, 1984), and there is also controversy concerning the range of IQs over which the IQ/IT relationship holds. A recent review by Nettlebeck (1982) suggests that many of the reported correlations between IT and IQ measures may have been inflated by including subjects having lower than average intelligence; however, other authors (e.g., Brand & Deary, 1982) maintain that the finding of a strong relationship between IT and IQ does not appear to be critically dependent on the inclusion of low IQ subjects.

Research using RT procedures dating back to the turn of the century has been regarded as demonstrating little relationship between RT and intelligence measures. However, recent advances in electronic technology have permitted time to be measured more precisely, and, more important, RT (decision-making) to be separated from movement time (MT) (muscle response); accordingly, this view has been revised. Several investigators (e.g., Carlson & Jensen, 1982; Jensen, 1980; Vernon, 1983) have found promising results using RT measures. These researchers have reported that the linear increase in RT to visual or auditory stimuli as a function of the amount of information presented is negatively correlated with IQ; that is, the brighter the subject, the less his or her reaction time is slowed by presenting more complicated stimuli.

The present study is a first attempt by this Center to examine whether IT and RT measures provide useful data, given the range of aptitude found in military populations. Further, by analyzing the experimental IT and RT measures in conjunction with scores from traditional tests, it is hoped the role of cognitive speed in mental functioning will be better understood.

APPROACH

Criteria

The Navy's basic electricity and electronic (BE&E) preparatory schools provide students with technical knowledge and skills necessary for success in their follow-on "A" schools, which, in turn, provide training for specialized positions in the Navy. Therefore, predicting progress in and successful completion of BE&E school is an important means of determining, at minimum, short-term performance in the Navy.

The BE&E schools employ a self-paced computer-managed instruction system. Students must demonstrate 100 percent mastery on a given module before being allowed to proceed to new material.

For purposes of this study, two performance measures in BE&E school were used as the criteria: (1) score obtained (percentage of items correct) on the comprehensive exam given on modules 20-25, and (2) time to learn (TTL); that is, the time the student needed to complete the first 25 modules. Module 25 was used as a cut-off since only a small number of subjects received instruction beyond this point. TTL is regarded as being a sensitive and reliable measure of individual differences (Gettinger, 1984).

Other data available included the subject's scores on the tests of the Armed Services Vocational Aptitude Battery (ASVAB). In addition, information was obtained from the subjects regarding their vision, state of fatigue, smoking habits, and handedness.

Procedure

A total of 155 incoming students at the BE&E School at the Naval Training Center, San Diego, were administered a battery of IT and RT tests between January and March of 1983. The battery took approximately 1 hour to administer on a TRS-80 microcomputer and comprised the following:

1. Three IT tests with horizontal lines on single planes:

    a. Dashed lines (12.7mm and 15.9mm long), dashed mask.

b. Dashed lines (12.7mm and 15.9mm long), solid mask.
c. Solid lines (12.7mm and 15.9mm long), solid mask.

2. Three IT tests with horizontal lines on separate planes:

   a. Dashed lines (12.7mm and 15.9mm long), dashed mask.
   b. Dashed lines (12.7mm and 15.9mm long), solid mask.
   c. Solid lines (12.7mm and 15.9mm long), solid mask.

3. Two IT tests with vertical lines:

   a. Dashed lines (33.7mm and 44.5mm long), dashed mask.
   b. Solid lines (19mm and 22.2mm long), solid mask.

4. One RT test with one-, three-, or five-key choice tasks.

The IT graphic displays were created using the TRS-80 character set and the POKE command in TRS-80 BASIC. Line lengths differed for the vertical and horizontal displays due to the limited graphic capabilities of the apparatus.[1] All tests were adaptive; that is, they were made easier or harder in response to the subject's performance. Subjects responded by pressing specified keys on the TRS-80 keyboard. The initial display durations were relatively long in order to build subject confidence through a series of correct responses. In the disp'ay duration algorithm, if the subject made two consecutive correct answers, he or she was allowed to attempt the next higher level of difficulty. However, if the subject made an error, the test decreased in difficulty and the rate at which the test difficulty converged was reduced (i.e., size of the variations in stimulus duration was decreased). The briefest display durations were approximately 40 milliseconds (msec).

In the RT test, subjects were presented with one, three, or five open squares on the screen and instructed to press the appropriate numbered key as quickly as possible after a square was filled in (see Figure 1). At the beginning of each trial, the subject held down the space bar until one of the stimulus squares was filled in. His RT was the number of msec between the onset of the stimulus (square filled in) and the instant he released the space bar. His movement time (MT) was the number of msecs between release of the space bar and the pressing of the correctly numbered response key.

Before each test, students were given instructions and several practice trials, until it was clear that they understood the task. After each presentation, they were provided with performance feedback via computer display. If, on an IT test, a subject made two consecutive correct responses at the highest level of difficulty, the test was terminated and the subject was assigned a score of "1." (The scale the subjects saw was reversed, with 1000 being the highest possible score.) Otherwise, a subject was tested until he had made 11 errors on each IT test; his or her score was based on the final display speed.

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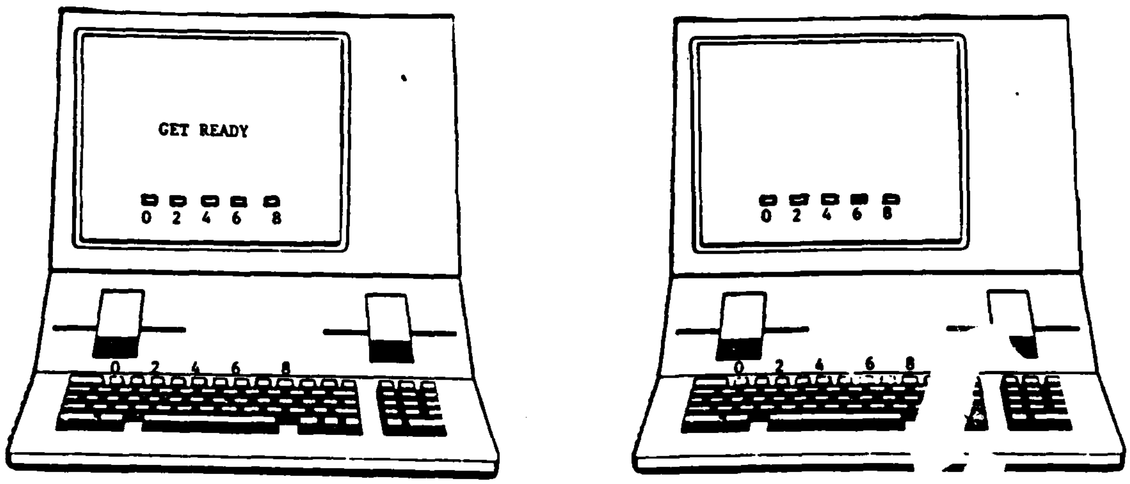
[1]The TRS-80 was selected, despite its limitations, because an extensive library of relevant software, including reaction time and inspection time, were commercially available for the TRS-80. However, these programs proved unsuitable and new ones were written.



a. Subject is told to get ready to respond.

b. As soon as a square (6 above) is filled in, the subject must press the corresponding key (#6) as rapidly as possible.

Figure 1. Example RT test with five-choice task.

Analysis

Zero-order and multiple correlations were computed among the cognitive speed measures and the school performance criteria.

RESULTS

Since this was an exploratory study, the intention was to develop a variety of IT tests to investigate display characteristics (i.e., dashed or solid lines, vertical or horizontal, one or two planes) that might increase test effectiveness. The students experienced no trouble in understanding the instructions and most seemed to enjoy their participation. The students proved to be more able than anticipated and on one test (1c), over one half achieved the highest possible score.

An additional problem involved loss of subjects due to conflicting demands on the students' time. Although all 155 subjects took the RT test, not all completed the IT part of the test battery. Also, preliminary analysis indicated that the female members of the sample (N = 11), had significantly slower reaction and movement times under all three RT conditions. Further, the relationships between the RT measures obtained by the females and the school criterion variables were in the opposite direction than those for males. It was decided that the final sample should include only the male subjects who took the entire test battery (N = 112).

There were no significant correlations between performance on the cognitive speed measures and corrected vision, near/far sightedness, or self-reported fatigue. Chi-square analyses indicated no significant effects attributable to test administrator, race, or handedness.

One-, three-, and five-key reaction and movement times were selected as the best predictors, along with IT tests 1b, 2c, and 3a because (1) they had the highest correlations with school progress and (2) they represented different types of stimulus displays.

The distribution statistics for the criterion measures are presented in Table 1. Both measures are distributed with acceptable symmetry, making transformations unnecessary.

Table 1

BE&E School Criterion Measures

	Mean	Median	Standard Deviation
Comprehensive exam score (% correct)	85.3	84.1	6.99
Time to complete the first 25 modules (hours)	325.0	312.0	79.69

Table 2 presents the intercorrelations between the cognitive speed measures. Although most of the RT and IT tests are significantly related to one another, some of the correlations, particularly those for IT tests, are quite low. The intercorrelation between the school performance criteria--time required to complete the first 25 modules (TIME 25) and the score on the module 25 exam (COMP 25)--was -.43 ($p < .001$).

Table 2 also presents the correlations between the cognitive speed measures and the school performance criteria. The best predictors from among the RT measures were 5-key RT and, unexpectedly, 1-key movement time. For the IT tests, a composite measure based on the subject's average z-score for IT tests 1b, 2c, and 3a was the best predictor of school success, with significant relationships to both performance criteria. Combining the 5-key RT and the composite IT score yielded a multiple R of .53 ($p < .01$) in predicting time to complete modules 1-25. It would be of interest to compare the cognitive speed tests with the tests used operationally in selecting and assigning students to the BE&E school; however, for several reasons, there is no statistically valid way of making such a comparison. One problem resides in the use of a variety of test composites in assigning students to the school, depending on what naval rating they will be assigned after graduation. Nevertheless, as a rough approximation of operational test validity, scores on the Armed Forces Qualification Test (AFQT) were correlated with time to learn, the result being a validity coefficient of .38. Because the AFQT subtests incurred some restriction in range, having been used to some extent in selecting students, and because

Table 2

Correlation Matrices

Variable	1KEYRT	3KEYRT	5KEYRT	1KEYMT	3KEYMT	5KEYMT	MEDSLOPE	IT1b	IT2c	IT3a	IT AVG
Intercorrelations Between Cognitive Speed Measures (N - 112)											
1KEYRT[a]	1.0000	--	--	--	--	--	--	--	--	--	--
3KEYRT[a]	0.3673***	1.0000	--	--	--	--	--	--	--	--	--
5KEYRT[a]	0.3320***	0.7800***	1.0000	--	--	--	--	--	--	--	--
1KEYMT[a]	0.1677*	0.2122*	0.1930*	1.0000	--	--	--	--	--	--	--
3KEYMT[a]	0.3013***	0.3038***	0.2096*	0.6559***	1.0000	--	--	--	--	--	--
5KEYMT[a]	0.2193**	0.3319***	0.2829**	0.4445***	0.7584***	1.0000	--	--	--	--	--
MEDSLOPE[b]	-0.5635***	0.3694***	0.5921***	0.0258	-0.0738	0.0603	1.0000	--	--	--	--
IT1b[c]	0.1071	0.1721*	0.2307**	0.0248	-0.0913	-0.1038	0.1106	1.0000	--	--	--
IT2c[c]	0.0873	0.1681*	0.1595*	-0.0141	0.0110	0.1042	0.0651	0.2079*	1.0000	--	--
IT3a[c]	0.1030	0.2274**	0.2506**	-0.0992	0.0829	0.2598**	0.1315	0.0432	0.2976***	1.0000	--
ITAVG[d]	0.1467	0.2797**	0.3163***	-0.0464	-0.0033	0.1227	0.1516	0.6214***	0.7453***	0.6608***	--
Correlations Between Cognitive Speed Measures and Performance Measures ($81 \leq N \leq 86$)											
COMP25	-0.1423	-0.2898**	-0.2913**	-0.3249**	-0.2427*	-0.2862**	-0.1315	-0.1440	-0.1287	-0.1204	-0.1869*
TIME25	0.1318	0.2232*	0.3509***	0.0741	0.1079	0.0932	0.1913*	0.2722**	0.4188***	0.3586***	0.4964***

[a]Based on the median of 11 trails.
[b]Represents the slope of RT medians across conditions.
[c]Based on the final display speed for each IT test.
[d]Average z score of the three IT tests.

*p<.05.
**p<.01.
***p<.001.

the .53 value for the cognitive speed tests represents an unshrunken multiple R, the cognitive speed and AFQT tests may be similar in validity for the present population.[2]

None of the experimental measures were predictive of academic disenrollment.

DISCUSSION AND CONCLUSIONS

As a preliminary attempt to adapt IT methodology to microcomputers, the present study provided mixed results. The problem with many of the experimental tests being too easy demonstrates the need for an apparatus capable of extremely brief display durations. The fact that the intercorrelations between the tests themselves were low is also cause for concern, although this may be partly due to the presence of a ceiling effect on some of the tests. Follow-on research with higher capability instrumentation has been initiated to further clarify this issue.

The data for RT also pose a problem. The finding that MT was sometimes a better predictor of performance than RT was unexpected. However, it should be noted that the correlation between RT and school performance increased as the RT task increased in complexity, implying that raising the number of response options beyond the maximum of five used in this study may result in a stronger link between RT and school performance. The inverse relationship between RT and school performance among females was also unexpected and does not appear to have been reported elsewhere in the literature. However, because of the small number of women in the sample it probably is unwise to draw conclusions without further data.

As indicated previously, a controversy exists concerning the relationship between cognitive speed and more traditional measures of intelligence (e.g., Nettlebeck & Kirby, 1983; Hulme & Turnbull, 1983). Nevertheless, the findings of the present study suggest that the experimental cognitive speed tests, if presented on a higher capability apparatus, might make a significant contribution to the prediction of training performance. However, many issues remain to be clarified, including the optimal length, configuration, and orientation of the IT display lines, the fairness of RT and IT tests for female subjects, and the exact nature of the relationship between cognitive speed measures and more traditional indices of aptitude. Follow-on work is expected to shed more light on these and other aspects of cognitive speed research.

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[2]When the relationships between the 5-key RT test, the composite IT measure, and the ASVAB test scores were examined, IT was found to be most strongly related to the ASVAB Mechanical Comprehension and Auto and Shop Information tests ($r = .35$ and $.33$), while RT correlated with the Attention to Detail and Auto and Shop Information tests ($r = .53$ and $.32$). Inspection and reaction time generally were not related to ASVAB tests used to measure general intellectual ability (e.g., Arithmetic Reasoning and Word Knowledge).

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